Profiling Dissipation Measurements using χpods on Moored Profilers in Luzon Strait

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LONG-TERM GOALS

The long-term goal of this program is to understand the physics of small-scale oceanic processes and how they affect the larger scales of ocean circulation. Ongoing studies within the **Ocean Mixing Group** at OSU emphasize observations, interaction with turbulence modelers and an aggressive program of sensor / instrumentation development and integration.

OBJECTIVES

The principal objectives of this project are to:

- quantify the energy losses to turbulence dissipation in the Luzon Strait in a systematic, comprehensive and extended way;
- quantify the spring-neap variation in these energy losses;
- obtain meaningful, long-term observations of the turbulent heat and momentum flux profiles in Luzon Strait, from which useful parameterizations can be derived;

APPROACH

To accomplish these objectives, we have:

1. modified 2 McLane Moored Profilers MPs for direct and extended measurements of turbulence, and
2. built, deployed and analyzed data from additional fixed-point turbulence measurements on IWISE moorings

WORK COMPLETED

We worked with engineers from the Applied Physics Lab at University of Washington to modify 2 MPs to house new pressure cases with analog electronics, fast thermistor sensors, analog-to-digital conversion electronics and batteries (Figure 1).

Report Documentation Page

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Initial engineering tests in December 2009 in Puget Sound prompted refinements which were incorporated into the unit deployed in Luzon Strait for the 2010 field campaign. Following this successful deployment (Figure 2), an additional MP was modified and 2 units deployed in Luzon Strait for the 2011 field campaign.
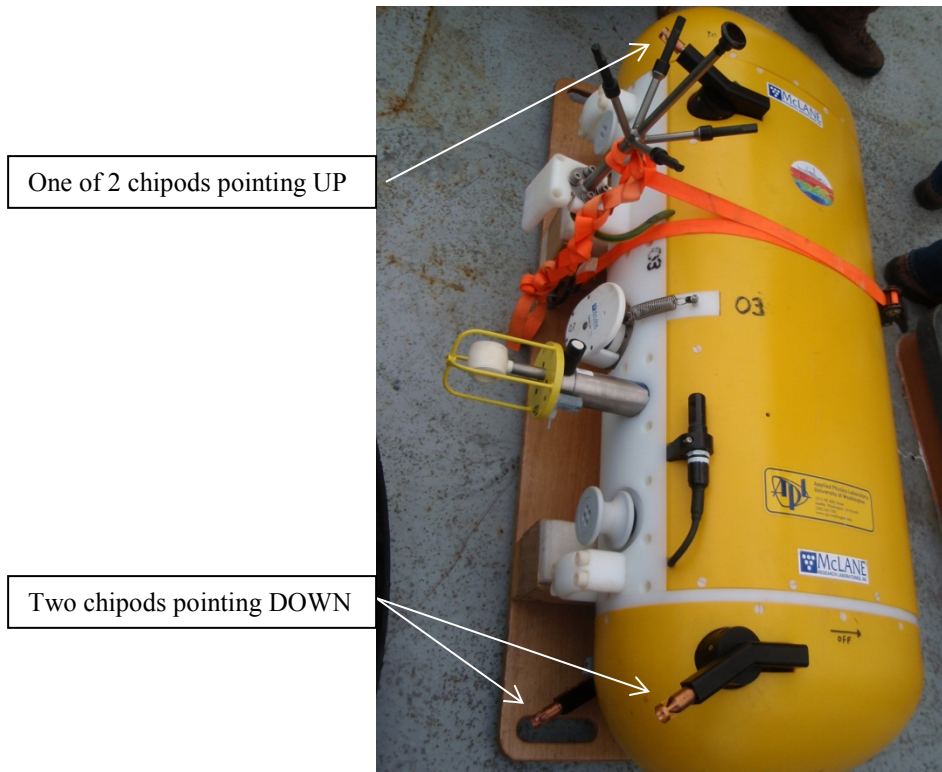

Figure 1 – turbulence-resolving χpods on one (of 2) Moored Profilers deployed in Luzon Strait in summer 2011. Two chipods point UP on the upper part of the MP, two point DOWN on the lower part. The UP/DOWN concept permits a measurement of undisturbed flow when the MP profiles both UP and DOWN.

An additional 5 individual moored chipods were deployed in the IWISE 2011 mooring array (A1, N1, N2). Two of these were deployed at 2000 m depth below the MP chipod units, a depth greater than all previous chipod measurements. These were equipped with a new pitot sensor designed to provide mean flow speeds (as well as turbulent velocity fluctuations) for incorporation into chipod temperature variance dissipation rate calculations.

RESULTS

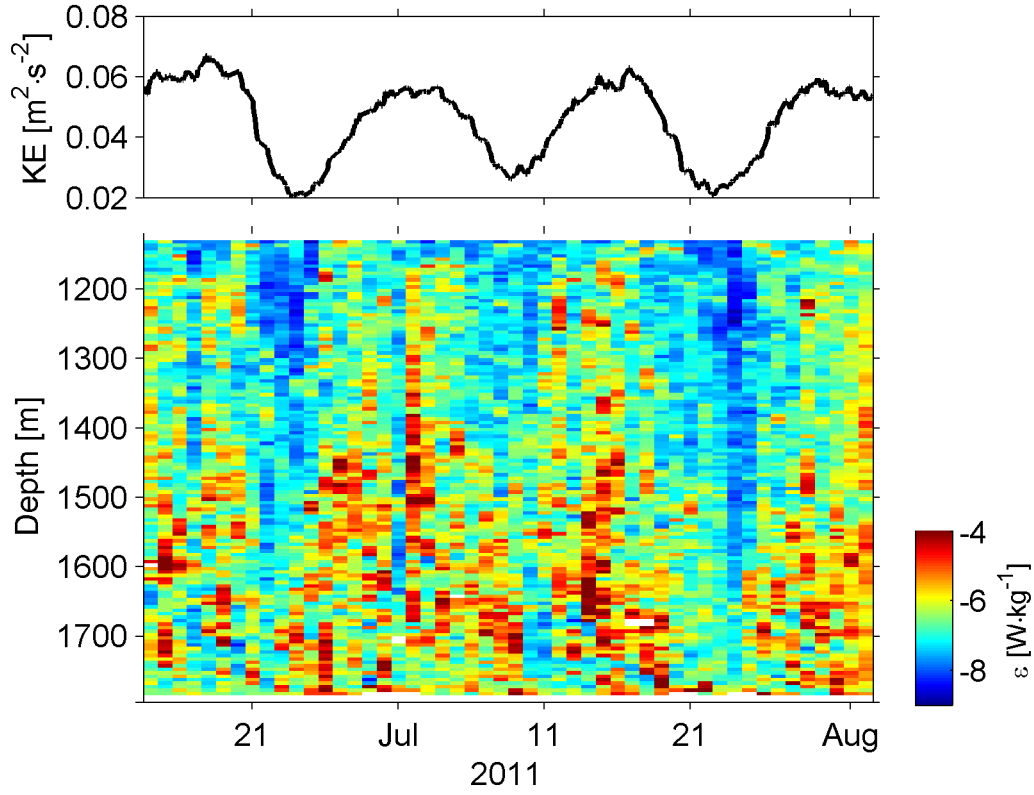Summary examples of data results are shown in Figs. 2-5.

Figure 2 –Continuous deep-ocean turbulence profiling measurements using turbulence resolving chipods on a moored profiler. The upper panel shows vertically-averaged kinetic energy and the bottom panel turbulence kinetic energy dissipation rate (ε). These measurements were made on mooring N2 in Luzon Strait in summer 2011.
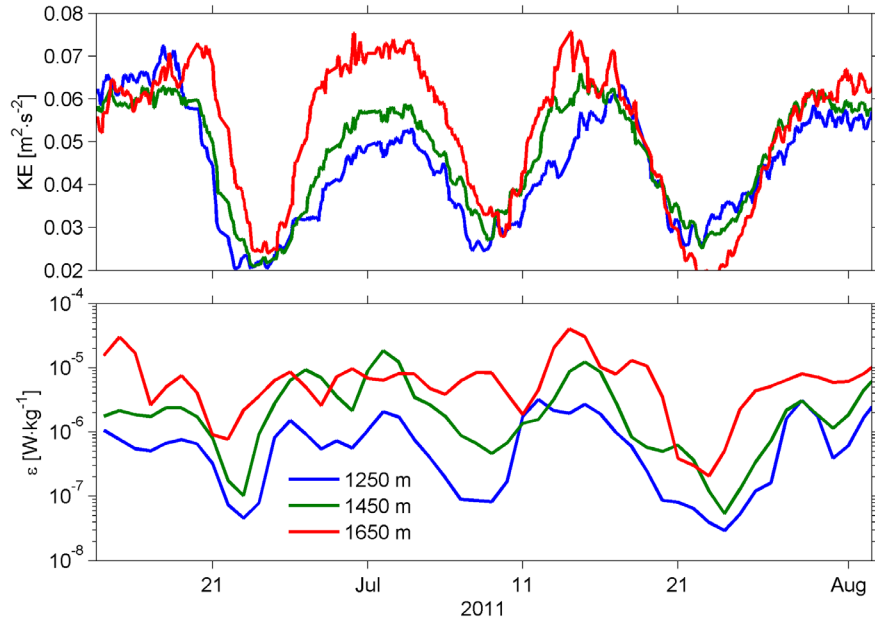
Figure 3 –Summary of measurements from moored profiler at N2 in Luzon Strait summer 2011 shown in Fig. 2. Upper panel shows vertically-averaged KE in 200 m intervals. Beneath is shown vertically-averaged dissipation rate over the same intervals.
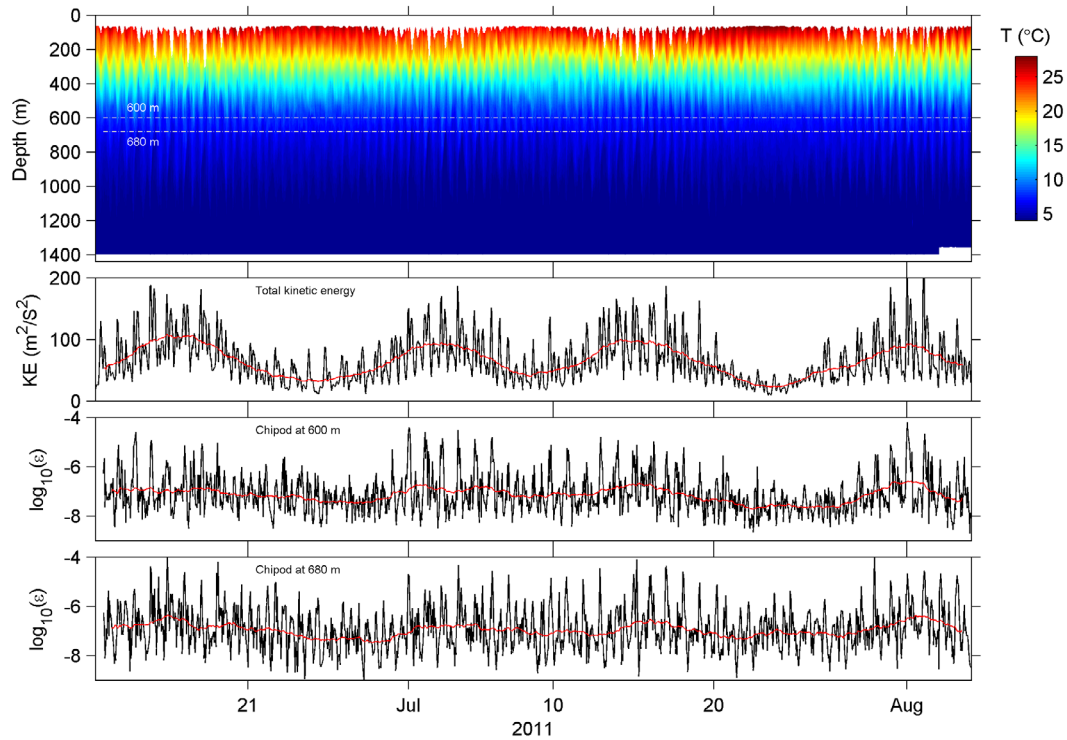

Figure 4 –Summary of measurements from mooring A1 in Luzon Strait summer 2011. Upper panel temperature with locations of 2 chipods indicated by the dashed lines. Beneath are shown vertically-averaged kinetic energy plus dissipation rates from each chipod.
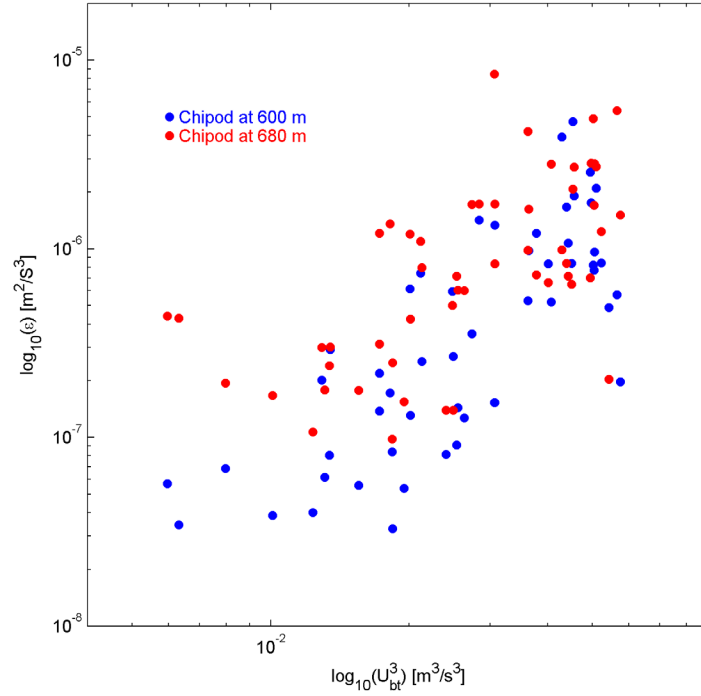
Figure 5 –Comparison of daily-averaged dissipation rates from Fig. 4 and cubed barotropic currents.

A new velocity measurement: A fundamental requirement to compute χ_T and ε_χ from temperature gradient measurements is the flow speed past the sensor tip. This is necessary to convert measured frequency spectra to wavenumber spectra to which a universal form is compared by scaling (Moum & Nash 2009). A significant part of this signal is the motion of the cable itself (Perlin and Moum 2012), but it also requires a measure of the current speed, which to date has required χpods to be deployed near a stand-alone velocity sensor. In some cases, this requirement has been inconvenient as it controls the χpod placement, and it is possibly the weakest part of the measurement, only partly because the velocity sensors are typically sampled too slowly. To address this issue, we have devoted considerable effort to develop a local measure of velocity using a differential pressure sensor – a pitot tube. The design is based on that used by Moum (1990) to measure turbulent velocities with our vertical profiler *Chameleon*. The basic problem with previous incarnations was the absolute pressure-dependence of almost all differential pressure sensors – that is, increased ambient pressure causes an increased voltage in the absence of any differential pressure. This essentially excludes the sensor from measurement of mean speed.

We have recently found a new differential pressure sensor that minimizes this common-mode pressure signal, have characterized its (small) common-mode pressure dependence and temperature dependence and have carried out extensive wind tunnel testing. The first deployment was on a mooring in Luzon Strait in summer 2011 at 2000 m depth (Fig. 6). The comparison of velocity from a nearby ADCP with large spatial and temporal averaging is very good (Fig. 7). Furthermore, the high-frequency part of the signal (sampled at 50 Hz) indicates the presence of an inertial subrange coincident with turbulence sensed by the temperature sensor on the χpod. Comparisons of ε computed directly by scaling the inertial subrange of the velocity spectra to ε_χ derived indirectly from χ show statistical agreement on 5-

minute spectral estimates within 20%. Another advantage of the complementary measurement of velocity fluctuations is evidenced just past 18:00 in Fig. 6 where the bottom boundary layer became well-mixed, reducing temperature stratification and thereby precluding any assessment of turbulence based on temperature gradient fluctuations alone
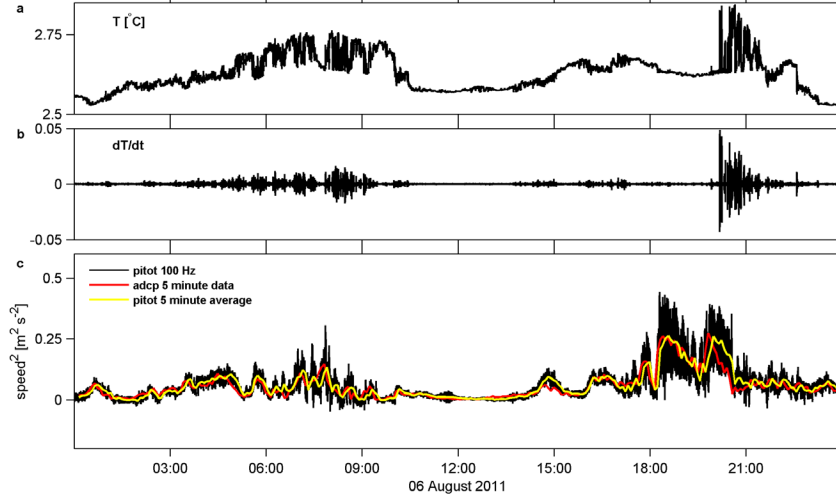

Figure 6 – A single day of a 2-month time series from a χpod moored at 2000 m depth on mooring N1 in Luzon Strait. a) temperature; b) time derivative of temperature (dT/dt), from which χ_T is computed; c) velocity from a nearby ADCP (red) and from a pitot tube on the χpod (black at 50 Hz, yellow averaged to match ADCP). The pitot velocity was derived from a static lab calibration of pressure and Bernoulli, $u = \sqrt{2p/\rho}$.
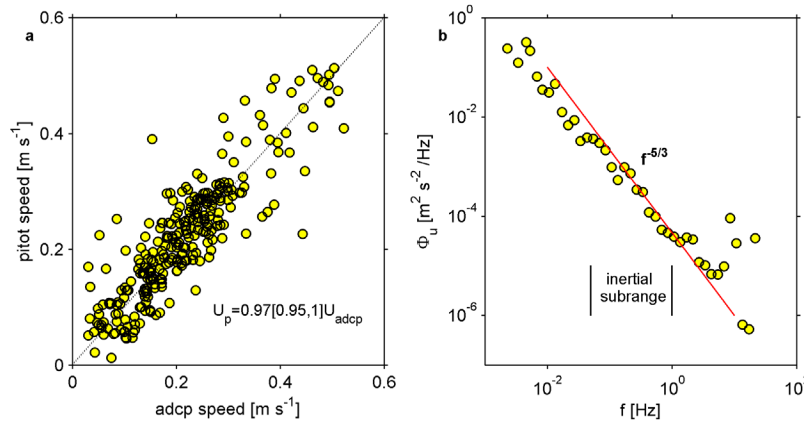

Figure 7 – Mean and turbulent velocities from a high-speed pitot tube on χpod . a) direct comparison of ADCP and pitot velocities; b) velocity spectrum computed from 30 minutes of data from the pitot tube starting at 18:00. Estimates of ε derived from inertial subrange fits to the velocity spectrum agree statistically to within 20% of estimates of ε_χ from temperature gradient measurements on the same χpod (Figure 6b).

The additional estimate of ε from velocity measurements on χpods is a bonus. However, the most significant result is that the local measurement of current speed makes χpod a standalone measurement. Where velocity measurements do not exist, this provides them.

IMPACT/APPLICATION

The development of a chipod for moored profilers offers a new way to obtain long time series of turbulence in the deep ocean. Development of a new, small, inexpensive, low power velocity sensor offers simultaneous measurements of both current speed and turbulence.

RELATED PROJECTS

The dissipation measurements derived from the chipods on moorings A1, N1 and N2 are being used to validate inferred estimates of turbulence from other platforms. Together, these are contributing to larger IWISE effort by providing a temporal and spatial assessment of dissipation and mixing in Luzon Strait. Some of the measurements are currently being used by Byungho Lim as part of his MS thesis project. This project has relied on the IWISE mooring project of Matthew Alford (APL/UW).

The development of our new velocity measurement of both mean+turbulence scales has led to additional deployments of two new chipods (plus 6 high-resolution pressure pods) in Cordova Channel off SE Alaska as part of a Naval Research Lab experiment on Breaking Wave Effects under High Winds (BWE; David Wang, Paul Hwang, Hemantha Wijesekera). Deployments will take place October 2012.

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HONORS/AWARDS/PRIZES

James N. Moum, Oregon State University, Fellow, American Geophysical Union, 2012